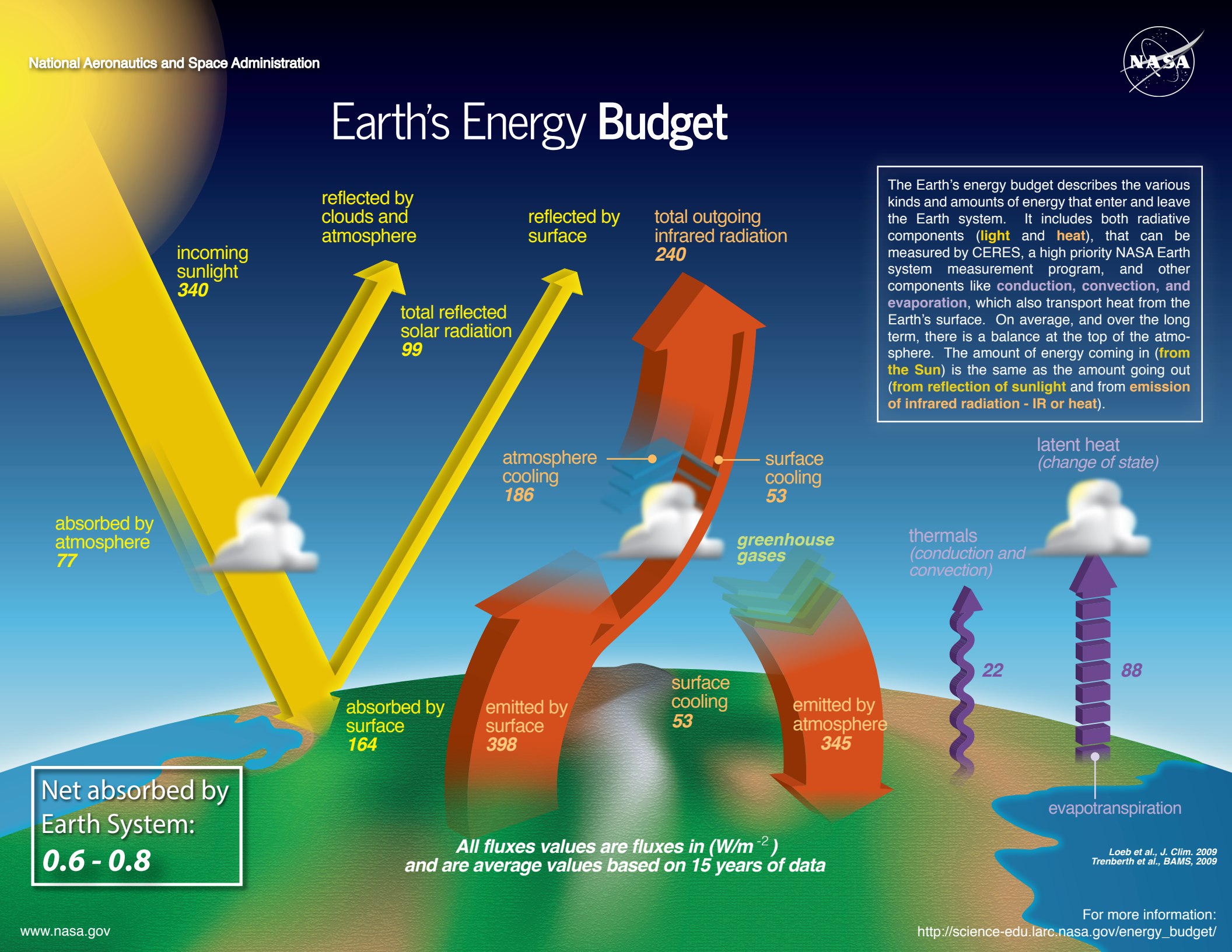
National Aeronautics and Space Administration

Earth's Energy **Budget**

The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both radiative components (**light** and **heat**), that can be measured by CERES, a high priority NASA Earth system measurement program, and other components like **conduction, convection, and evaporation**, which also transport heat from the Earth's surface. On average, and over the long term, there is a balance at the top of the atmosphere. The amount of energy coming in (**from the Sun**) is the same as the amount going out (**from reflection of sunlight** and from **emission of infrared radiation - IR or heat**).



Net absorbed by Earth System: **0.6 - 0.8**

All fluxes values are fluxes in (W/m^{-2}) and are average values based on 15 years of data

Loeb et al., J. Clim. 2009
Trenberth et al., BAMS, 2009

www.nasa.gov

For more information:
http://science-edu.larc.nasa.gov/energy_budget/

BALANCING THE ENERGY BUDGET

For a stable climate, the energy budget of the Earth should be balanced. In equation form:

Energy In = **Energy Out**

The balance can be considered at several levels in the Earth System:

At the top of the atmosphere, the energy coming in from the Sun is balanced by sunlight reflected back to space and the net infrared emission (IR) from the Earth. The equation is:

Incoming Sun = **Sunlight reflected from clouds/atmosphere/surface + IR emission**

At the Earth's surface, absorbed sunlight is balanced by the net IR emission and the conduction/convection and evapotranspiration. The equation is:

Sunlight absorbed + IR emitted by atmosphere (greenhouse effect) = **IR emission + Thermals + Evapotranspiration**

These balance equations are for an equilibrium state of the Earth. Equilibrium would be expected for a planet that has spent a long time in a stable solar system, but sometimes changes occur that take the system out of balance. For example, the ice ages occurred because of long-term changes in Earth's orbit around the Sun, which resulted in a change to the distribution of the "Sunlight In" term. Over time, reflected sunlight and IR emission changed to balance the first equation. The result was a colder surface and major glacial advances.

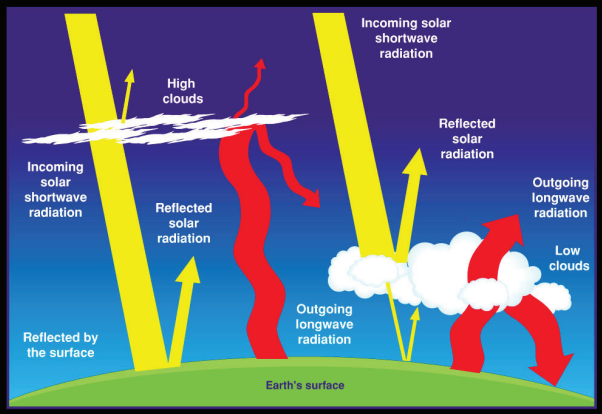
Over the last 15 years, measurements show that the Earth's energy budget is not quite balanced. There has been a net ~0/2% of energy absorbed per year - meaning more energy in than energy out.

CASE STUDY: Surface Effects on Energy Budget
CHANGES IN CENTRAL AUSTRALIA

While the energy budget averaged over the globe changes little from year-to-year, on a local or regional basis large changes can occur due to changes in the Earth's surface or atmosphere. For one example, this graph shows the change in net radiation over a region, approximately 2 million km^2, of Central Australia. The area experienced a multiyear drought from 2002-2009, during which time the region went from being a net absorber to a net emitter of energy, largely due to a change from plant-covered ground to dry soil. Heavy rainfall in 2010 broke the drought, resulting in a large increase in vegetation and soil moisture and a return to net absorption of energy.

Similar changes occur on a smaller scale whenever human activities change the surface of the Earth. *Loeb et al., IJC, 2016.*

Cloud Effects On Earth's Radiation



Clouds are a major variable in Earth's energy budget. As shown on the reverse, clouds affect both reflected energy and emitted heat.

Clouds can act to either warm or cool the Earth. High clouds are often thin and not very reflective, letting lots of the Sun's light in. The air temperature is quite cold at high levels; so they do not emit a lot of heat. High clouds tend to warm the Earth.

Low clouds are often quite thick and reflect lots of sunlight back to space. They are also lower in the atmosphere where the air is warmer so they emit more heat. Low clouds tend to cool the Earth.

You can observe clouds to help ground truth NASA satellite observations.
http://www.globe.gov/globe-data/data-entry/globe-observer

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